CLAIMS

1. A laser comprising:

a laser medium comprising $H_2(1/p)$ where p is an integer and $1 < p \leq 137$,

a cavity,

and a power source to form an inverted population in an energy level of $H_2(1/p)$.

2. The laser of claim 1 further comprising cavity mirrors and a laser-beam output.

3. The laser of claim 1 wherein the power source forms excited vibration-rotational levels of $H_2(1/p)$ and lasing occurs with a stimulated transition from at least one vibration-rotational level to at least another lower-energy-level other than one with a significant Boltzmann population at the cell neutral-gas temperature such as one with both υ and $J = 0$ wherein the vibration-rotational levels of $H_2(1/p)$ comprise the inverted population.

4. The laser of claim 1 wherein the laser light is within the range of wavelengths from about infrared, visible, ultraviolet, extreme ultraviolet, to soft X-ray.

5. The laser of claim 1 wherein the laser medium may further comprise an activator molecule.

6. The laser of claim 5 wherein the activator molecule is at least one of O_2, N_2, CO_2, CO, NO_2, NO, XX' where each of X and X' is a halogen atom.

5. The laser of claim 3 wherein the vibration-rotational excitation may be by at least one of a direct collisional excitation and an energy exchange with an excited state species such as an excited activator molecule.

6. The laser of claim 3 wherein the direct excitation and the excitation of the activator may be by collision with an energetic particle.

7. The laser of claim 6 further comprising a particle beam.

8. The laser of claim 7 wherein the particle beam is an electron beam.

9. The laser of claim 6 wherein the power source accelerates the energetic species.

10. The laser of claim 9 wherein the power source to cause energetic species may be at least one of a particle beam such as an electron beam and microwave, high voltage, and RF discharges.

11. The laser of claim 5 further comprising a mean to energetically excite the activator molecule such as at least one of a particle beam such as an electron beam, microwave, glow, and RF discharge power.

12. The laser of claim 1 wherein the pumping power source may a particle bean such as an electron beam.

13. The laser of claim 12 wherein the beam energy may be in the range of about 0.1 to 100 MeV, preferably on the range of about 10 eV to 1 MeV, more preferably in the range of about 100 eV to 100 keV, and most preferably in the range of about 1 keV to 50 keV.

14. The laser of claim 12 wherein the beam current may be in the range of about 0.01 μA to 1000 A, preferably on the range of about 0.1 μA to 100 A, more preferably in the range of about 1 μA to 10 A, and most preferably in the range of about 10 μA to 1 A.

15. The laser of claim 3 wherein the vibrational energies are given by

$$E_{vib} = p^2 0.515902\ eV$$

and the rotational energies are given by

$$E_{rot} = E_{J+1} - E_J = \frac{\hbar^2}{I}[J+1] = p^2(J+1)0.01509\ eV$$

within at least one of about ±20%, ±10%, and ±5% where p is an integer greater than one and J is an integer.

16. The laser of claim 3 where the energies of the emission is given by

$$E_{vib-rot} = p^2 E_{vib\,\upsilon} \pm p^2 (J+1) E_{rot\,H_2}$$

wherein

$$E_{vib\,\upsilon} = \upsilon p^2 0.5159\ e\mathrm{V}$$

$$-\upsilon(\upsilon-1)\left(1.23981\,X\,10^{-4}\right)\frac{100hc\left(8.06573X10^3\ \frac{cm^{-1}}{eV} p^2 0.5159\ eV\right)^2}{4e\left(p^2 4.151\ eV + p^3 0.326469\ eV\right)}\ e\mathrm{V}$$

and the rotational energies are given by

$$E_{rot} = E_{J+1} - E_J = \frac{\hbar^2}{I}[J+1] = p^2 (J+1) 0.01509\ eV$$

within at least one of about ±20%, ±10%, and ±5% where $\upsilon = 0,1,2,3\ldots$integer, p is an integer greater than one, and J is an integer.

17. The laser of claim 1 wherein the medium is at least one of $H_2(1/12)$, $H_2(1/13)$, and $H_2(1/14)$.

18. The laser of claim 17 wherein the wavelength is useful for EUV lithography in the range of 5-20 nm.

19. The laser of claim 18 wherein the wavelength is useful for EUV lithography and the mirrors comprise multilayer, thin film coatings such as distributed Bragg reflectors.

20. The laser of claim 19 wherein the wavelength is at least one of about 13.4 nm and 11.3 nm and the mirrors comprise $Mo:Si$ ML.

21. The laser of claim 1 wherein the exit for the beam output is an ultraviolet transparent window such as a MrF_2 window.

22. The laser of claim 1 wherein the beam output is a differentially pumped pin-hole optic.

23. The laser of claim 8 wherein the cavity further comprises an electron window such as a SiN_x foil window.

24. The laser of claim 3 wherein the emission is due to at least

one of the transitions P(1), P(2), P(3), P(4), P(5), and P(6) of $H_2(1/4)$ 154.94 nm, 159.74 nm, 165.54 nm, 171.24 nm, 178.14 nm, and 183.14 nm, respectively, and transitions between these corresponding states.

25. A laser comprising:

a plasma forming cell or reactor for the catalysis of atomic hydrogen producing power, a continuous stationary inverted $H_2(1/p)$ population where p is an integer and $1 < p \leq 137$, and novel hydrogen species and compositions of matter comprising new forms of hydrogen,

a source of catalyst,

a source of atomic hydrogen, and

a mean to form and output a laser beam.

26. The laser of claim 25 wherein the cell is capable of maintaining a vacuum or pressures greater than atmospheric pressure.

27. The laser of claim 25 wherein the catalysis of atomic hydrogen generates a plasma, power, and novel hydrogen species and compositions of matter comprising new forms of hydrogen.

28. The laser of claim 25 wherein the means to form an output a laser beam comprises a cavity, cavity mirrors, and a beam output.

29. The laser of claim 28 wherein the cavity comprises a reactor to catalyze atomic hydrogen to lower-energy states such as an rt-plasma reactor, plasma electrolysis reactor, barrier electrode reactor, RF plasma reactor, pressurized gas energy reactor, gas discharge energy reactor, microwave cell energy reactor, a combination of a glow discharge cell and a microwave and/or RF plasma reactor, and an electron-beam plasma reactor.

30. The laser of claim 25 wherein the reactor comprises a source of hydrogen; one of a solid, molten, liquid, and gaseous source of catalyst; a vessel containing hydrogen and the catalyst wherein the reaction to form lower-energy hydrogen occurs by contact of the hydrogen with the catalyst; and a means for providing the lower-energy hydrogen product $H_2(1/p)$ to the laser

cavity to comprise the laser medium.

31. The laser of claim 1 wherein the cavity comprises a reactor to catalyze atomic hydrogen to lower-energy states, and a plasma is maintained by a particle beam such as an electron beam.

32. The laser of claim 25 wherein a plasma provides atomic hydrogen, or the cell further comprises a dissociator such as a filament, or metal such as platinum, palladium, titanium, or nickel that forms atomic hydrogen from the source of atomic hydrogen.

33. The laser of claim 25 where the source of catalyst is an excimer.

34. The laser of claim 33 wherein the excimer is at least one of He_2*, Ne_2*, Ne_2*, and Ar_2* and the catalyst is He^+, Ne^+, Ne^+/H^+ or Ar^+.

35. The laser of claim 33 wherein the excimer is formed by a high pressure discharge.

36. The laser of claim 35 wherein the discharge is one of a microwave, glow, RF, and electron-beam discharge.

37. The laser of claim 25 comprising a noble-gas-catalyst source-hydrogen mixture which is maintained at high pressure in the range of about 100 mTorr to 100 atm, preferably in the range of about 10 Torr to 10 atm, more preferably in range of about 100 Torr to 5 atm, and most preferably in the range of about 300 Torr to 2 atm.

38. The laser of claim 25 further comprising a source of ionization to form the catalyst from the source of catalyst.

39. The laser of claim 38 wherein the source of ionization to form the catalyst from the source of catalyst is at least one of an electron beam and an ionizing species.

40. The laser of claim 39 wherein the ionizing species is an ion such as O^+.

41. The laser of claim 39 wherein the ionizing species reacts with a source of catalyst comprising a noble gas excimer to form the catalyst.

42. The laser of claim 41 wherein the source of catalyst is Ar_2*, the ionizing species is O^+ which reacts to form the catalyst according to the reaction:

$$Ar_2*+O^+ \rightarrow Ar + Ar^+ + O$$

43. The laser of claim 25 wherein the catalysis of hydrogen is maintained by a particle beam, microwave, glow, or RF discharge plasma of a source of atomic hydrogen and a source of catalyst such as argon to provide catalyst Ar^+.

44. The laser of claim 39 wherein a species such as oxygen may react with the source of catalyst such as Ar_2^* to form the catalyst such as Ar^+.

45. The laser of claim 1 wherein the he $H_2(1/p)$ pressure is maintained in the range of about 0.1 mTorr to 10,000 Torr, preferably the $H_2(1/p)$ pressure is in the range of 10 mTorr to 100 Torr; more preferable the $H_2(1/p)$ pressure is in the range of 10 mTorr to 10 Torr, and most preferably, the $H_2(1/p)$ pressure is in the range of 10 mTorr to 1 torr.

46. The laser of claim 1 where the $H_2(1/p)$ flow rate is preferably about 0-1 standard liters per minute per cm^3 of vessel volume and more preferably about 0.001-10 sccm per cm^3 of vessel volume.

47. The laser claim 1 wherein, the power density of the source of pumping power such as the electron-beam power is preferably in the range of about 0.01 W to about 100 W/cm^3 vessel volume; more preferably it is in the range of about 0.1 to 10 W/cm^3 vessel volume.

48. The laser of claim 5 wherein the mole fraction of activator gas is in the range of 0.001% to 90%. Preferably it

is in the range of about 0.01% to 10%, and most preferably it is in the range of about 0.01% to 1%. The flow rate and pressure are maintained according to that of $H_2(1/p)$ to achieve these desired mole fractions.

49. The laser of claim 1 further comprising a catalyst cell, a catalyst, and a source of hydrogen to catalyze the formation of hydrogen to lower-energy states.

50. The laser of claim 25 where the pumping power to form the inverted population is from at least one of the external power supply and the power released from the catalysis of atomic hydrogen to lower-energy states.

51. The laser of claim 6 wherein energetic particles are formed by the catalysis of atomic hydrogen.

52. The laser of claim 6 wherein the pumping excitation for the formation of the inverted population or the excitation of the activator is due to collisions with energetic particles formed by the catalysis of atomic hydrogen.

53. The laser of claim 1 comprising a source of $H_2(1/p)$.

54. The laser of claim 25 wherein $H_2(1/p)$ is generated insitu from the catalysis of hydrogen to lower-energy states given by

$$E_n = -\frac{e^2}{n^2 8\pi\varepsilon_o a_H} = -\frac{13.598\ eV}{n^2}$$

$$n = \frac{1}{2}, \frac{1}{3}, \frac{1}{4}, \ldots, \frac{1}{p}; \quad p \le 137$$

which further react to form $H_2(1/p)$.

55. The laser of claim 25 wherein the catalysis cell is also the laser cavity.

56. The laser of claim 25 wherein the reactor comprises a source of hydrogen; one of a solid, molten, liquid, and gaseous source of catalyst; a vessel containing hydrogen and the catalyst wherein the reaction to form lower-energy

hydrogen occurs by contact of the hydrogen with the catalyst; and a means for providing the lower-energy hydrogen product $H_2(1/p)$ to the laser cavity to comprise the laser medium.

57. The laser of claim 25 wherein the formation of the inverted population is due to at least one of input power and catalysis of atomic hydrogen to lower-energy states,

$H_2(1/p)$ is formed insitu due to the catalysis of atomic hydrogen,

the catalysis cell serves as the laser cavity, and

an inverted population may be formed due to at least one of catalysis of atomic hydrogen and input power.

58. The laser of claim 1 further comprising a catalyst-hydrogen mixture to achieve at least one of the formation of $H_2(1/p)$ and the formation of an inverted vibration-rotational population of $H_2(1/p)$.

59. The laser of claim 25 wherein the pressure of a mixture of a source of catalyst and atomic hydrogen source is maintained in the range of about 0.1 mTorr to 10,000 Torr, preferably the pressure in the range of 10 mTorr to 5000 Torr; more preferably, the pressure is in the range of 100 Torr to 2000 Torr, and most preferably, the pressure is in the range of 500 Torr to 1000 Torr.

60. The laser of claim 25 wherein the flow rate of the mixture of a source of catalyst and atomic hydrogen source is preferably about 0-1 standard liters per minute per cm^3 of vessel volume and more preferably about 0.001-10 sccm per cm^3 of vessel volume.

61. The laser of claims 1 and 25 wherein the power density of the source of pumping power such as the electron-beam power is preferably in the range of about 0.01 W to about 100 W/cm^3 vessel volume; more preferably it is in the range of about 0.1 to 10 W/cm^3 vessel volume.

62. The laser of claim 25 wherein the mole fraction of

hydrogen in the catalyst-hydrogen gas is in the range of 0.001% to 90%. Preferably it is in the range of about 0.01% to 10%, and most preferably it is in the range of about 0.1% to 5%. The mole fraction of activator gas is in the range of 0.001% to 90%. Preferably it is in the range of about 0.01% to 10%, and most preferably it is in the range of about 0.01% to 1%.

63. The laser of claim 62 wherein, the flow rate and pressure are maintained according to that of catalyst-hydrogen mixture to achieve these desired mole fractions.

64. The laser of claim 25 wherein the source of catalyst is helium, neon, and argon, and the catalyst is He^+, Ne^+, Ne^+/H^+ or Ar^+.

65. A laser comprising a laser cavity, cavity mirrors, and source of applied power to maintain a hydrogen catalysis reaction and an internal power source comprising a cell for the catalysis of atomic hydrogen to form novel hydrogen species and/or compositions of matter comprising new forms of hydrogen, and

at least one of the power from catalysis and an external power source maintains $H_2(1/p)$ in an excited vibration-rotational state from which stimulated emission may occur.

66. A light source comprising:

a light emitting medium comprising $H_2(1/p)$ where p is an integer and $1<p\leq 137$,

a cavity,

and a power source to cause the emission of light from an energy level of $H_2(1/p)$.

67. The light source of claim 66 wherein the emission is due to at least one of the transitions P(1), P(2), P(3), P(4), P(5), and P(6) of and R(0) of $H_2(1/4)$ 154.94 nm, 159.74 nm, 165.54 nm, 171.24 nm, 178.14 nm, 183.14 nm, and 146.84 nm, respectively, and transitions between these corresponding states.

68. The compound of claim 25 comprising

(a) at least one neutral, positive, or negative increased

binding energy hydrogen species having a binding energy

(i) greater than the binding energy of the corresponding ordinary hydrogen species, or

(ii) greater than the binding energy of any hydrogen species for which the corresponding ordinary hydrogen species is unstable or is not observed because the ordinary hydrogen species' binding energy is less than thermal energies at ambient conditions, or is negative; and

(b) at least one other element.

69. A compound of claim 25 or 68 characterized in that the increased binding energy hydrogen species is selected from the group consisting of H_n, H_n^-, and H_n^+ where n is a positive integer, with the proviso that n is greater than 1 when H has a positive charge.

70. A compound of claim 25 characterized in that the increased binding energy hydrogen species is selected from the group consisting of (a) hydride ion having a binding energy that is greater than the binding of ordinary hydride ion (about 0.8 eV) for $p=2$ up to 23 in which the binding energy is represented by

$$Binding\ Energy = \frac{\hbar^2\sqrt{s(s+1)}}{8\mu_e a_0^2\left[\frac{1+\sqrt{s(s+1)}}{p}\right]^2} - \frac{\pi\mu_0 e^2\hbar^2}{m_e^2}\left(\frac{1}{a_H^3}+\frac{2^2}{a_0^3\left[\frac{1+\sqrt{s(s+1)}}{p}\right]^3}\right)$$

where p is an integer greater than one, $s=1/2$, π is pi, $\hbar$ is Planck's constant bar, μ_o is the permeability of vacuum, m_e is the mass of the electron, μ_e is the reduced electron mass given by $\mu_e = \frac{m_e m_p}{\frac{m_e}{\sqrt{\frac{3}{4}}}+m_p}$ where m_p is the mass of the proton, a_H is the radius of the hydrogen atom, a_o is the Bohr radius, and e is the elementary charge; (b) hydrogen atom having a binding energy greater than about 13.6 eV; (c) hydrogen molecule having a first binding energy greater than about 15.3 eV; and (d) molecular hydrogen ion having a binding energy greater than about 16.3 eV.

71. A compound of claim 70 characterized in that the increased

binding energy hydrogen species is a hydride ion having a binding energy of about 3, 6.6, 11.2, 16.7, 22.8, 29.3, 36.1, 42.8, 49.4, 55.5, 61.0, 65.6, 69.2, 71.6, 72.4, 71.6, 68.8, 64.0, 56.8, 47.1, 34.7, 19.3, and 0.69 eV.

72. A compound of claim 71 characterized in that the increased binding energy hydrogen species is a hydride ion having the binding energy:

$$Binding\ Energy = \frac{\hbar^2\sqrt{s(s+1)}}{8\mu_e a_0^2\left[\frac{1+\sqrt{s(s+1)}}{p}\right]^2} - \frac{\pi\mu_0 e^2\hbar^2}{m_e^2}\left(\frac{1}{a_H^3} + \frac{2^2}{a_0^3\left[\frac{1+\sqrt{s(s+1)}}{p}\right]^3}\right)$$

where p is an integer greater than one, $s=1/2$, π is pi, $\hbar$ is Planck's constant bar, μ_o is the permeability of vacuum, m_e is the mass of the electron, μ_e is the reduced electron mass given by $\mu_e = \frac{m_e m_p}{\frac{m_e}{\sqrt{\frac{3}{4}}} + m_p}$ where m_p is the mass of the proton, a_H is the radius of the hydrogen atom, a_o is the Bohr radius, and e is the elementary charge.

73. A compound of claim 25 characterized in that the increased binding energy hydrogen species is selected from the group consisting of

(a) a hydrogen atom having a binding energy of about $\frac{13.6\ eV}{\left(\frac{1}{p}\right)^2}$ where p is an integer,

(b) an increased binding energy hydride ion (H^-) having a binding energy of about

$$Binding\ Energy = \frac{\hbar^2\sqrt{s(s+1)}}{8\mu_e a_0^2\left[\frac{1+\sqrt{s(s+1)}}{p}\right]^2} - \frac{\pi\mu_0 e^2\hbar^2}{m_e^2}\left(\frac{1}{a_H^3} + \frac{2^2}{a_0^3\left[\frac{1+\sqrt{s(s+1)}}{p}\right]^3}\right)$$

where p is an integer greater than one, $s=1/2$, π is pi, $\hbar$ is Planck's constant bar, μ_o is the permeability of vacuum, m_e is the mass of the electron, μ_e is the reduced electron mass given by

$\mu_e = \frac{m_e m_p}{\frac{m_e}{\sqrt{\frac{3}{4}}} + m_p}$ where m_p is the mass of the proton, a_H is the radius of the hydrogen atom, a_o is the Bohr radius, and e is the elementary charge;

(c) an increased binding energy hydrogen species $H_4^+(1/p)$;

(d) an increased binding energy hydrogen species trihydrino molecular ion, $H_3^+(1/p)$, having a binding energy of about $\frac{22.6}{\left(\frac{1}{p}\right)^2} eV$ where p is an integer,

(e) an increased binding energy hydrogen molecule having a binding energy of about $\frac{15.3}{\left(\frac{1}{p}\right)^2} eV$; and

(f) an increased binding energy hydrogen molecular ion with a binding energy of about $\frac{16.3}{\left(\frac{1}{p}\right)^2} eV$.

74. The catalyst of claim 25 comprising a chemical or physical process that provides a net enthalpy of $m \cdot 27.2 \pm 0.5\, eV$ where m is an integer or $m/2 \cdot 27.2 \pm 0.5\, eV$ where m is an integer greater than one.

75. The catalyst of claim 25 that provides a net enthalpy of $m \cdot 27.2 \pm 0.5\, eV$ where m is an integer or $m/2 \cdot 27.2 \pm 0.5\, eV$ where m is an integer greater than one corresponding to a resonant state energy level of the catalyst that is excited to provide the enthalpy.

76. The cell of claim 25 wherein a catalytic system is provided by the ionization of t electrons from a participating species such as an atom, an ion, a molecule, and an ionic or molecular compound to a continuum energy level such that the sum of the ionization energies of the t electrons is approximately $m \cdot 27.2 \pm 0.5\, eV$ where m is an integer or $m/2 \cdot 27.2 \pm 0.5\, eV$ where m is an integer greater than one and t is an integer.

77. The plasma cell of claim 25 wherein the catalyst is provided

by the transfer of t electrons between participating ions; the transfer of t electrons from one ion to another ion provides a net enthalpy of reaction whereby the sum of the ionization energy of the electron donating ion minus the ionization energy of the electron accepting ion equals approximately $m \cdot 27.2 \pm 0.5\,eV$ where m is an integer or $m/2 \cdot 27.2 \pm 0.5\,eV$ where m is an integer greater than one and t is an integer.

78. The catalyst of claims 74, 75, 76, and 77 wherein preferably m is an integer less than 400.

79. The catalyst of claim 75 comprising He^{+} which absorbs $40.8\,eV$ during the transition from the $n=1$ energy level to the $n=2$ energy level which corresponds to $3/2 \cdot 27.2\,eV$ ($m=3$) that serves as a catalyst for the transition of atomic hydrogen from the $n=1$ ($p=1$) state to the $n=1/2$ ($p=2$) state.

80. The catalyst of claim 25 comprising Ar^{2+} which absorbs $40.8\,eV$ and is ionized to Ar^{3+} which corresponds to $3/2 \cdot 27.2\,eV$ ($m=3$) during the transition of atomic hydrogen from the $n=1$ ($p=1$) energy level to the $n=1/2$ ($p=2$) energy level .

81. The catalyst of claim 25 is selected from the group of Li, Be, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Kr, Rb, Sr, Nb, Mo, Pd, Sn, Te, Cs, Ce, Pr, Sm, Gd, Dy, Pb, Pt, He^{+}, Na^{+}, Rb^{+}, Sr^{+}, Fe^{3+}, Mo^{2+}, Mo^{4+}, and In^{3+}.

82. A catalyst of atomic hydrogen of claim 25 capable of providing a net enthalpy of $m \cdot 27.2 \pm 0.5\,eV$ where m is an integer or $m/2 \cdot 27.2 \pm 0.5\,eV$ where m is an integer greater than one and capable of forming a hydrogen atom having a binding energy of about $\frac{13.6\,eV}{\left(\frac{1}{p}\right)^2}$ where p is an integer wherein the net enthalpy is provided by the breaking of a molecular bond of the catalyst and the ionization of t electrons from an atom of the broken molecule each to a continuum energy level such that the sum of the bond energy and the ionization energies of the t electrons is approximately $m \cdot 27.2 \pm 0.5\,eV$ where m is an integer or $m/2 \cdot 27.2 \pm 0.5\,eV$ where m is an integer greater than one.

83. The catalyst of claim 25 comprising at least one of C_2, N_2, O_2, CO_2, NO_2, and NO_3.

84. The catalyst of claim 1 comprising a molecule in combination with an ion or atom catalyst.

85. The catalyst combination of claim 84 comprising at least one molecule selected from the group of C_2, N_2, O_2, CO_2, NO_2, and NO_3 in combination with at least one atom or ion selected from the group of Li, Be, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Kr, Rb, Sr, Nb, Mo, Pd, Sn, Te, Cs, Ce, Pr, Sm, Gd, Dy, Pb, Pt, Kr, He^+, Na^+, Rb^+, Sr^+, Fe^{3+}, Mo^{2+}, Mo^{4+}, In^{3+}, He^+, Ar^+, Xe^+, Ar^{2+} and H^+, and Ne^+ and H^+.

86. The catalyst of claim 25 comprising helium excimer, Ne_2*, which absorbs $27.21\,eV$ and is ionized to $2Ne^+$, to catalyze the transition of atomic hydrogen from the (p) energy level to the ($p+1$) energy level given by

$$27.21\ eV + Ne_2* + H\left[\frac{a_H}{p}\right] \rightarrow 2Ne^+ + H\left[\frac{a_H}{(p+1)}\right] + [(p+1)^2 - p^2]X13.6\ eV$$

$$2Ne^+ \rightarrow Ne_2* + 27.21\ eV$$

And, the overall reaction is

$$H\left[\frac{a_H}{p}\right] \rightarrow H\left[\frac{a_H}{(p+1)}\right] + [(p+1)^2 - p^2]X13.6\ eV$$

87. The catalyst of claim 25 comprising helium excimer, He_2*, which absorbs $27.21\,eV$ and is ionized to $2He^+$, to catalyze the transition of atomic hydrogen from the (p) energy level to the ($p+1$) energy level given by

$$27.21\ eV + He_2* + H\left[\frac{a_H}{p}\right] \rightarrow 2He^+ + H\left[\frac{a_H}{(p+1)}\right] + [(p+1)^2 - p^2]X13.6\ eV$$

$$2He^+ \rightarrow He_2* + 27.21\ eV$$

And, the overall reaction is

$$H\left[\frac{a_H}{p}\right] \rightarrow H\left[\frac{a_H}{(p+1)}\right] + [(p+1)^2 - p^2]X13.6\ eV$$

88. The catalyst of claim 25 comprising two hydrogen atoms which absorbs $27.21\,eV$ and is ionized to $2H^+$, to catalyze the

transition of atomic hydrogen from the (p) energy level to the $(p+1)$ energy level given by

$$27.21\ eV+2H\left[\frac{a_H}{1}\right]+H\left[\frac{a_H}{p}\right]\rightarrow 2H^{+}+2e^{-}+H\left[\frac{a_H}{(p+1)}\right]+[(p+1)^2-p^2]X13.6\ eV$$

$$2H^{+}+2e^{-}\rightarrow 2H\left[\frac{a_H}{1}\right]+27.21\ eV$$

And, the overall reaction is

$$H\left[\frac{a_H}{p}\right]\rightarrow H\left[\frac{a_H}{(p+1)}\right]+[(p+1)^2-p]X13.6\ eV$$

89. A catalytic disproportionation reaction of atomic hydrogen wherein lower-energy hydrogen atoms, hydrinos, can act as catalysts because each of the metastable excitation, resonance excitation, and ionization energy of a hydrino atom is $m\,X\,27.2\ eV$.

90. The catalytic reaction of claim 66 of a first hydrino atom to a lower energy state affected by a second hydrino atom involves the resonant coupling between the atoms of m degenerate multipoles each having $27.21\ eV$ of potential energy.

91. The catalytic reaction of claim 89 wherein the energy transfer of $m\,X\,27.2\ eV$ from the first hydrino atom to the second hydrino atom causes the central field of the first atom to increase by m and its electron to drop m levels lower from a radius of $\frac{a_H}{p}$ to a radius of $\frac{a_H}{p+m}$.

92. The catalytic reaction of claim 89 wherein the second interacting lower-energy hydrogen is either excited to a metastable state, excited to a resonance state, or ionized by the resonant energy transfer.

93. The catalytic reaction of claim 89 wherein the resonant transfer may occur in multiple stages.

94. The catalytic reaction of claim 93 wherein a nonradiative transfer by multipole coupling may occur wherein the central field of the first increases by m, then the electron of the first

drops m levels lower from a radius of $\frac{a_H}{p}$ to a radius of $\frac{a_H}{p+m}$ with further resonant energy transfer.

95. The catalytic reaction of claim 89 wherein the energy transferred by multipole coupling may occur by a mechanism that is analogous to photon absorption involving an excitation to a virtual level.

96. The catalytic reaction of claim 89 wherein the energy transferred by multipole coupling during the electron transition of the first hydrino atom may occur by a mechanism that is analogous to two photon absorption involving a first excitation to a virtual level and a second excitation to a resonant or continuum level.

97. A catalytic reaction with hydrino catalysts for the transition of $H\left[\frac{a_H}{p}\right]$ to $H\left[\frac{a_H}{p+m}\right]$ induced by a multipole resonance transfer of $m \cdot 27.21\ eV$ and a transfer of $[(p')^2-(p'-m')^2]\ X\ 13.6\ eV - m \cdot 27.2\ eV$ with a resonance state of $H\left[\frac{a_H}{p'-m'}\right]$ excited in $H\left[\frac{a_H}{p'}\right]$ is represented by

$$H\left[\frac{a_H}{p'}\right]+H\left[\frac{a_H}{p}\right] \rightarrow$$
$$H\left[\frac{a_H}{p'-m'}\right]+H\left[\frac{a_H}{p+m}\right]+[\left((p+m)^2-p^2\right)-\left(p'^2-(p'-m')^2\right)]\ X\ 13.6\ eV$$

where p, p', m, and m' are integers.

98. The catalytic reaction with hydrino catalysts wherein a hydrino atom with the initial lower-energy state quantum number p and radius $\frac{a_H}{p}$ may undergo a transition to the state with lower-energy state quantum number $(p+m)$ and radius $\frac{a_H}{(p+m)}$ by reaction with a hydrino atom with the initial lower-energy state quantum number m', initial radius $\frac{a_H}{m'}$, and final radius a_H that provides a net enthalpy of $m \cdot 27.2 \pm 0.5\ eV$ where m is an integer or $m/2 \cdot 27.2 \pm 0.5\ eV$ where m is an integer greater

than one.

99. The catalytic reaction of claim 98 of hydrogen-type atom, $H\left[\frac{a_H}{p}\right]$, with the hydrogen-type atom, $H\left[\frac{a_H}{m'}\right]$, that is ionized by the resonant energy transfer to cause a transition reaction is represented by

$$m\,X\,27.21\ eV + H\left[\frac{a_H}{m'}\right] + H\left[\frac{a_H}{p}\right] \rightarrow$$

$$H^+ + e^- + H\left[\frac{a_H}{(p+m)}\right] + [(p+m)^2 - p^2 - (m'^2 - 2m)]X13.6\ eV$$

$$H^+ + e^- \rightarrow H\left[\frac{a_H}{1}\right] + 13.6\ eV$$

And, the overall reaction is

$$H\left[\frac{a_H}{m'}\right] + H\left[\frac{a_H}{p}\right] \rightarrow$$

$$H\left[\frac{a_H}{1}\right] + H\left[\frac{a_H}{(p+m)}\right] + \left[2pm + m^2 - m'^2\right]X13.6\ eV + 13.6\ eV$$

100. The cell for the catalysis of atomic hydrogen of claim 25 wherein the catalyst comprises a mixture of a first catalyst and a source of a second catalyst.

101. The mixture of a first catalyst and a source of a second catalyst of claim 100 wherein the first catalyst produces the second catalyst from the source of the second catalyst.

102. The first catalyst of claim 101 that produces the second catalyst from the source of the second catalyst wherein the energy released by the catalysis of hydrogen by the first catalyst produces a plasma in the energy cell.

103. The first catalyst of claim 101 that produces the second catalyst from the source of the second catalyst wherein the energy released by the catalysis of hydrogen by the first catalyst ionizes the source of the second catalyst to produce the second catalyst.

104. A laser comprising:

a plasma forming cell or reactor for the catalysis of atomic hydrogen producing power, a continuous stationary inverted $H_2(1/p)$ population where p is an integer and $1<p\leq 137$, and novel hydrogen species and compositions of matter comprising new forms of hydrogen,

a source of catalyst,

a source of atomic hydrogen,

a controller to cause atomic hydrogen to react with atomic hydrogen to form lower-energy states given by

$$E_n=-\frac{e^2}{n^2 8\pi\varepsilon_o a_H}=-\frac{13.598\ eV}{n^2} \text{ and } H_2(1/p)$$

$$n=\frac{1}{2},\frac{1}{3},\frac{1}{4},\ldots,\frac{1}{p};\quad p\leq 137, \text{ and}$$

a means to form and output a laser beam.

105. The laser of claim 1 wherein the power source comprises a means to replace the electron deficit due to the higher electron mobility compared to ions to control the plasma potential.

106. The laser of claim 105 further comprising a source of electrons to control the plasma potential.

107. The laser of claim 106 wherein the source of electrons is a current from a hot filament or an electron gun.

108. The laser of claim 1 wherein the power source comprises a means to magnetize the electrons to control the plasma potential.

109. The laser of claims 106 and 108 wherein the plasma potential is maintained at a desired potential of about neutral, positive, or negative potential.

110. The laser of claim 109 wherein the plasma potential is controlled to optimize the rate of the catalysis of hydrogen to lower-energy states given by

$$E_n=-\frac{e^2}{n^2 8\pi\varepsilon_o a_H}=-\frac{13.598\ eV}{n^2}$$

$$n=\frac{1}{2},\frac{1}{3},\frac{1}{4},\ldots,\frac{1}{p};\quad p\leq 137$$

111. The laser of claim 108 wherein the magnetic flux is in the range

of about 1-100,000 G, preferably the flux is in the range of about 10-1000 G, more preferably the flux in the range of about 50-200 G, most preferably the flux is the range of about 50-150 G.

112. The laser of claims 105 and 108 wherein further comprising a means to measure the plasma potential and a feedback loop of the electron flow and the electron confinement to maintain a desired plasma potential to cause a desired rate of hydrogen catalysis.

113. The laser of claim 112 wherein the plasma potential measurement means comprises a probe such as a Langmuir probe.

114. The laser of claim 107 wherein the source of electrons is a tungsten filament or a rhenium, BaO-coated, or radioactive filament such as a thoriated-tungsten filament.

115. The laser of claim 106 wherein the electron source is an electron emitter a heated alkali (Group I) metal or an alkaline earth (Group II) metal or a thermionic cathode.

116. The laser of claims 114 and 115 wherein the filament ionizes the catalyst such as Sr^+ or Ar^+, and the formed-rt-plasma maintains the ionization at a much higher level.

117. The laser of claim 108 wherein the means to confine electrons with a magnetic field is a magnetic bottle or a selenoidal field.

118. The laser of claim 106 wherein the source of electrons is a discharge electrode such as an anode.

119. The laser of claim 107 further comprising a controller wherein the electron flow to the plasma is controlled by controlling the temperature of the filament or the current of the electron gun.

120. The laser of claim 105 further comprising a means to confine electrons in a desired spatial region by an electric field.

121. The laser of claim 120 further comprising electrodes to provide the electric field.

122. The laser of claim 1 further comprising a source of negative ions

to control the plasma potential.

123. The laser of claim 122 wherein the source of negatively charged ions is a source of hydride ions.

124. The laser of claim 122 comprising a heating means wherein negative ions such as hydride ions are boiled from the surface of the wall of the reactor by maintaining the wall at an elevated temperature.

125. The laser of claim 1 further comprising a means to maintain a positive plasma potential.

126. The laser of claim 125 further comprising a source of positively charged ions to control the plasma potential.

127. The laser of claim 125 further comprising a means to confine positive ions.

128. The laser of claim 127 wherein the means to confine positve ions is a magnetic field such as a magnetic bottle or a selenoidal field.

129. The laser of claim 125 further comprising a means to confine electrons in a region such that a desired region outside of the electron-rich region is positively charged.

130. The laser of claim 129 wherein the means to confine electrons is a magnetic field such as a magnetic bottle or a selenoidal field.

131. The laser of claim 126 wherein the source of ions is an ion beam or a discharge electrode such as a cathode.

132. The laser of claim 127 wherein the means to confine positive ions in a desired spatial region comprises a source of electric field.

133. The laser of claim 132 wherein the source of electric field is electrodes.

134. The laser of claim 126 wherein the source of positively charged ions is a source of alkali (Group I) or alkaline earth (Group II) ions.

135. The laser of claim 126 further comprising a heating means wherein positive ions such as alkali or alkaline earth ions are boiled from the surface of the wall of the reactor by maintaining the wall at an elevated temperature.

136. The laser of claim 126 further comprising a heating means wherein the positive ions are provided by boiling off electrons to a different region such that electron-emitting source acquires a net positive charge that positively charges the plasma.

137. The laser of claim 136 wherein the electron-emitting source is a thermionic cathode.

138. A laser comprising:

a plasma forming cell or reactor for the catalysis of atomic hydrogen producing power, a continuous stationary inverted population with energy levels given by $p^2(0.515 \pm 0.151)eV$ where p is an integer and novel hydrogen species and compositions of matter comprising hydrogen,

a source of catalyst,

a source of atomic hydrogen,

a controller to cause atomic hydrogen to react with atomic hydrogen to cause EUV emission lines with energies of $q \cdot 13.6\ eV$ where q is an integer, and

a mean to form and output a laser beam.

139. The laser of claim 25 further comprising a means to provide water vapor to the plasma and a means to remove hydrogen and oxygen dissociated from the water vapor by the plasma such that the gases are collected as industrial gases.

140. The laser of claim 25 further comprising an electron beam from a gun wherein the beam energy is tunable and the free electrons serve as the catalyst wherein the free electrons undergo an inelastic scattering reaction with hydrogen atoms.

141. A laser produced by the inverted hydrogen population according to any of the preceding claims.

142. Use of the laser according to claim 141.

143. Electricity converted from photons produced the inverted hydrogen population according to any of the preceding claims.

144. Use of the electricity according to claim 143.

145. A source of light comprising:
a light emitting medium comprising $H_2(1/p)$ where p is an integer and $1 < p \leq 137$,
a cavity, and
a power source to form a light emitting state in said H_2.

146. Electricity converted from photons produced from the light source according to claim 145.

147. Use of the electricity according to claim 146.

148. A light source comprising:
a light emitting state of any lower-energy hydrogen species; and
a power source to form the light emitting state.